M e m o r a n d u m

Date: December 3, 2001

To: Tara Smith

From: Jamie Anderson
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Subject: DSM2 Fingerprinting Simulation for the In-Delta Storage Investigations

This memo documents a DSM2 fingerprinting study conducted as part of the In-Delta Storage investigations. As part of the analysis of the impacts of the In-Delta Storage alternatives on water quality concentrations in the Delta, an improved understanding of source and flow contributions throughout the Delta was desired. Thus, a DSM2 fingerprinting study was conducted to determine the relative contributions of the system inflows to total flow and water quality concentrations at selected Delta locations, including the original proposed Delta Wetlands project intake and release locations.

Relative flow contributions from six sources were examined for the time period March 1991 through September 1998. The six flow sources examined were the Sacramento River, San Joaquin River, Martinez, eastside streams, agricultural drains, and the Yolo Bypass. Simulation results are detailed in this memo for eight selected locations. Four of the analysis locations correspond to export locations: Old River Rock Slough, Old River at Highway 4 (Los Vaqueros), Clifton Court Forebay, and the Delta Mendota Canal intake. Four additional analysis locations correspond to the intakes for the original Delta Wetlands project: Webb Tract Intakes 1 and 2, and Bacon Island Intakes 1 and 2.

Since high DOC concentrations are typically an issue of concern during wet months, the finger printing results were analyzed on a monthly basis. Since DOC concentrations tend to increase after major rainfall events, monthly flow contributions for wet and critical years were analyzed separately. For all eight locations, the Sacramento River provided the major flow contribution during winters of critical years (56%-95%), and San Joaquin River flow contributions were highest during January of wet years (15%-62%). During winters of wet years San Joaquin River flow contributions increased at all locations, and in fact provided the majority of the flow at both the Clifton Court Intake and the Delta Mendota Canal. As might be expected based on their relative locations, San Joaquin River flow contributions were higher for the Bacon Island intake locations than for the Webb Tract locations in both wet and critical years. Agricultural drainage flow contributions were less than 6% at all locations except during January of wet years when the flow contributions increased up to 14%. Agricultural drainage concentrations were typically higher at the southern locations (the four export locations and at Bacon Island Intake 2) than at the more northern locations (the Webb Tract intakes and Bacon Island Intake 1).

Finger printing results for flow contributions for the winter months during wet and critical years were utilized to estimate ranges of DOC concentrations at the four export locations and at the four original Delta Wetlands intake locations. During December and January of critical years the highest average maximum DOC concentrations throughout the system were estimated when DOC concentrations in the Sacramento River were high since the Sacramento River provided the major flow contribution during those time periods. During December and January of critical years, varying the DOC concentrations in the San Joaquin River and in agricultural drainage produced minor changes in estimated DOC concentrations except at Clifton Court and the Delta Mendota Canal. This is due to the fact that the Clifton Court and Delta Mendota Canal sites were the only sites examined where the San Joaquin River made significant flow contributions during critical years. Additionally, flow contributions from agricultural drainage were less than 7% at all sites during critical years. In winters of wet years, the highest estimated DOC concentrations were associated with high DOC concentrations for the major flow contributor at each location (the Sacramento River for the In-Delta Storage and Old River intakes and the San Joaquin River for Clifton Court and the Delta Mendota Canal). In January of wet years, flow contributions from agricultural drainage increased to levels that produced the highest estimated DOC concentrations at all locations when the DOC concentrations of the agricultural drainage were high. Thus, a very high source DOC concentration can have a large impact on the total estimated DOC at a given location even if the flow contribution from that source is relatively minor.

In summary, DSM2 finger printing simulations were conducted to analyze the relative flow contributions of six sources throughout the Delta. Simulation results were examined at four export and the four original Delta Wetlands intake locations. Relative flow contributions from the six sources were analyzed as time series over the entire simulation period and on a monthly basis for both wet and critical years. The simulated relative flow contributions were then utilized to conduct a sensitivity analysis of estimated DOC concentrations at the eight study sites. Typically estimated DOC concentrations were highest when there were high DOC levels in the flow source that provided the major flow contribution for winters of both critical and wet years. However, during January of wet years, flow contributions from agricultural drainage increased to levels high enough that the highest estimated DOC concentrations were produced when the DOC concentrations of the agricultural drainage were high. The DSM2 finger printing technique provides a useful tool for sensitivity analysis of boundary condition effects on water quality at selected Delta locations.

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Introduction

For the In-Delta Storage project, DSM2 is being utilized to simulate dissolved organic carbon (DOC) concentrations for both base line and proposed operational alternatives. The proposed Delta Wetlands operational alternatives involve flooding four Delta islands (Figure 2). It is proposed to flood Webb Tract and Bacon Island during high flow periods. These islands would be utilized as in-Delta reservoirs that would provide storage for the water for use during lower flow periods. Additionally it is proposed to create shallow water habitat in the Delta by flooding Bouldin Island and Holland Tract. For this study, the original proposed Delta Wetlands intake and release locations were used (Figure 2). Later modifications to the proposed intake and release locations were not incorporated into this study. As part of the analysis of the impacts of the In-Delta Storage alternatives on water quality concentrations in the Delta, an improved understanding of source contributions throughout the Delta was desired. Thus, a DSM2 fingerprinting study was conducted to determine the relative contributions of the system inflows to total flow and water quality concentrations at selected Delta locations.

For this finger printing study, the DSM2 hydrodynamics and water quality validation simulations conducted by the DWR Delta Modeling Section were utilized as a base case. The validation simulation was conducted for the time period March 1991 through September 1998. The hydrology utilized in the validation study included a time varying representation of the tidal boundary at Martinez. For the validation, simulated water quality constituent concentrations were compared to observed concentrations. The validation studies are described in more detail in Nader-Tehrani (2001) and Pandey (2001).

For the validation finger printing study, relative flow contributions from six sources were examined. The six sources were the Sacramento River, San Joaquin River, Martinez, eastside streams, agricultural drains, and the Yolo Bypass. Conceptually the finger printing simulations could be thought of as collecting buckets of water from various locations throughout the Delta. Each bucket examined would contain water from each source (Figure 1), however the relative contributions from each source would vary at each location for each time period that a bucket of water was analyzed.

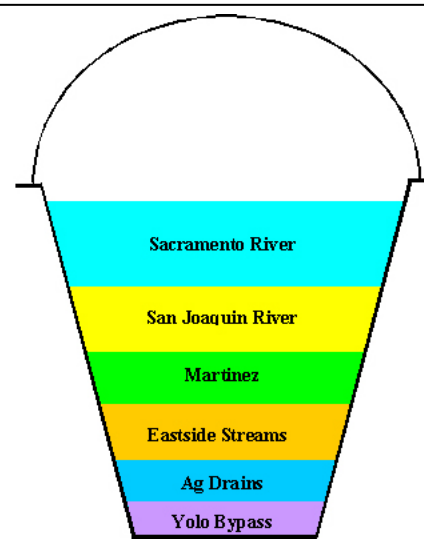


Figure 1: Conceptualization of Relative Source Contributions

The relative contributions of each flow source were simulated utilizing seven conservative tracer constituents denoted as CC1-CC7. Conservative tracer constituents 1 through 6 correspond to individual source locations (Figure 3). The constituent tracer concentrations were specified as a constant value at the source location (10,000 units in this case), and a value of zero is specified at all other locations. A seventh conservative tracer constituent is utilized to check mass conservation and is specified as the same constant value at each source (10,000 units in this case). Source concentrations are specified as 10,000 units to provide large concentrations that

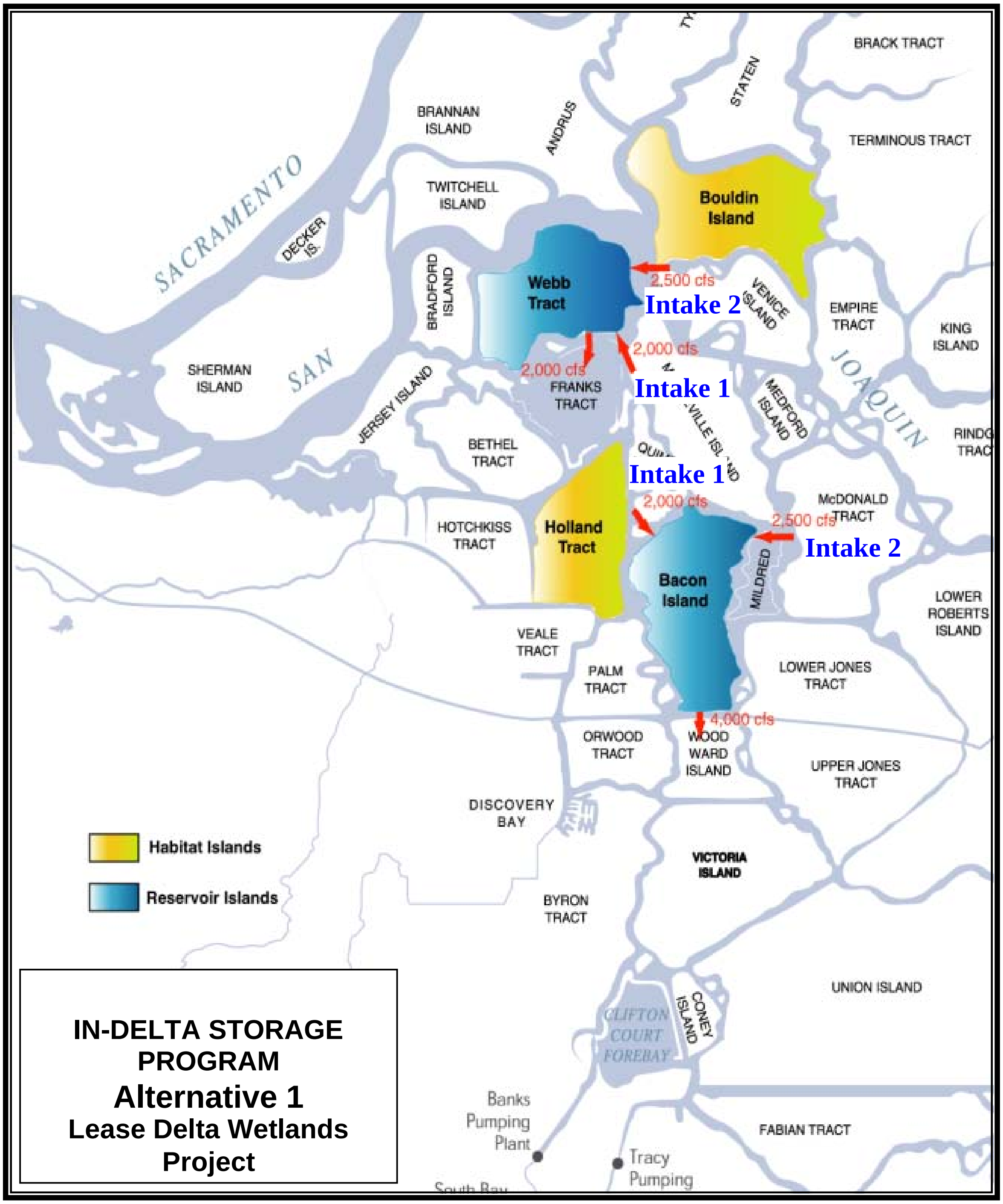


Figure 2: Proposed In-Delta Storage Alternative 1-Delta Wetlands Project with Original Intake and Release Locations

Figure adapted from draft document titled "In-Delta Storage Program: Description of Alternatives" dated 3/6/01

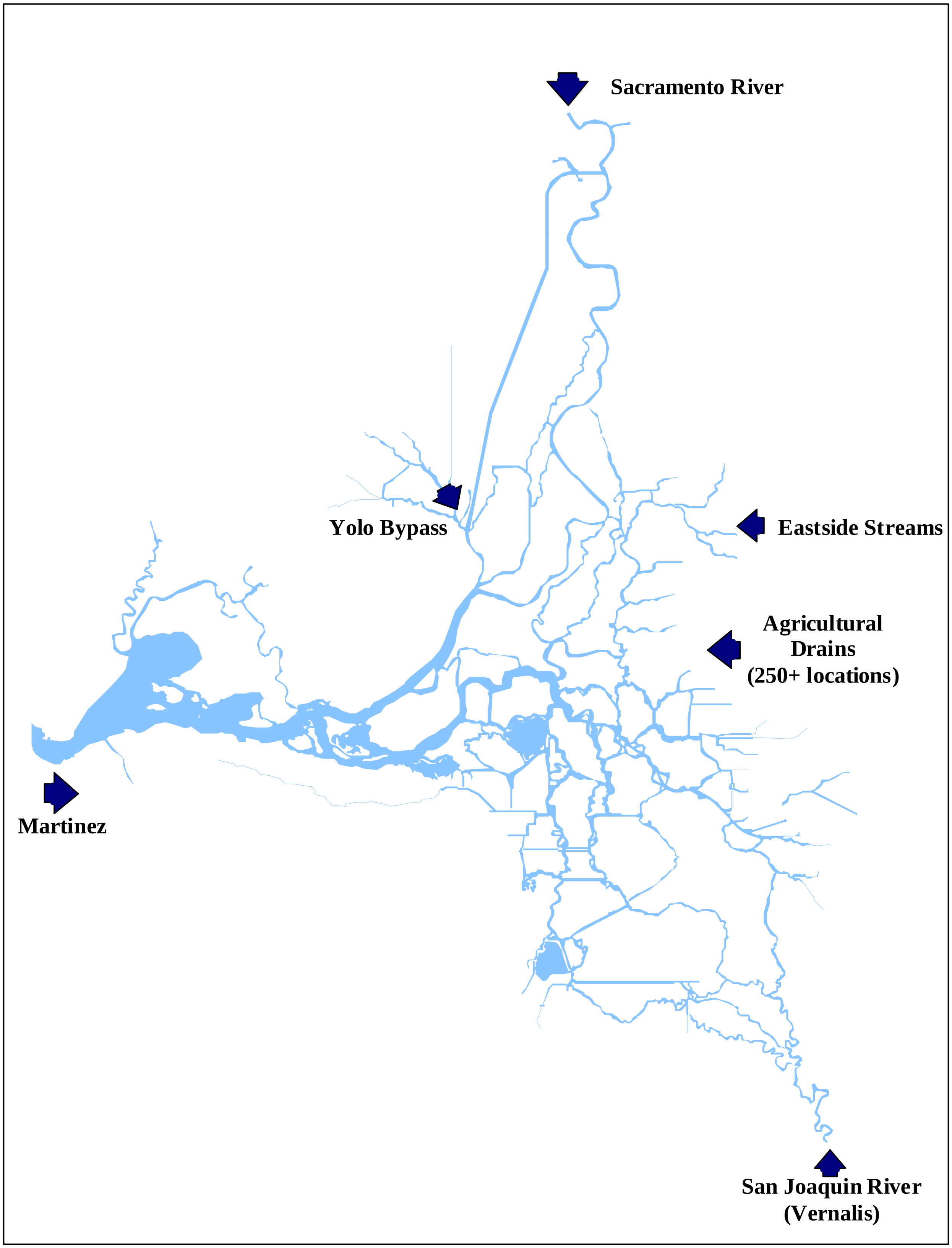


Figure 3: Source Locations for the Validation Fingerprinting Study

reduce round-off errors that occur at lower concentrations. Source locations corresponding to each conservative tracer constituent are indicated in Table 1. Specified concentrations of each conservative tracer constituent are given in Table 2.

Table 1: Conservative Tracer Constituents Simulated

Source Location	Conservative Constituent
Sacramento River	CC1
San Joaquin River	CC2
Martinez	CC3
Eastside Streams	CC4
Agricultural Drains	CC5
Yolo Bypass	CC6
All Sources	CC7

Table 2: Specified Source Tracer Concentations for In-Delta Storage Finger Printing

Location	CC1	CC2	CC3	CC4	CC5	CC6	CC7
Sac	10,000	0	0	0	0	0	10,000
SJR	0	10,000	0	0	0	0	10,000
Martinez	0	0	10,000	0	0	0	10,000
Eastside	0	0	0	10,000	0	0	10,000
Ag Drains	0	0	0	0	10,000	0	10,000
Yolo	0	0	0	0	0	10,000	10,000

If all of the initial conservative constituent tracer concentrations (CC1-CC6) are specified as the same constant value at the source location associated with each constituent and set equal to zero at all other source locations, when the system has reached dynamic steady state, the sum of the concentrations of conservative tracer constituents 1-6 at any location in the system should equal the specified concentration, 10,000 units in this case. Table 3 shows illustrative finger printing results for three hypothetical locations. At all three locations, the sum of the concentrations of conservative tracer constituents 1-6 equals the initial specified concentration of 10,000 units. For location A, the major source of water is the source associated with conservative tracer constituent 2 (the San Joaquin River-see Table 1) since 3500 units of the 10,000 units total concentration was contributed by that source. Similarly the source for conservative tracer constituent 3 (Martinez) is the major contributor at site B and the source associated with conservative tracer constituent 5 (agricultural drainage) is the main contributor at site C. For the example illustrated in Table 3, mass is conserved since the concentration of conservative tracer constituent 7 equals 10,000 units at all locations.

Table 3: Illustrative Examples of Finger Printing Conservative Tracer Constitutent Concentraitons at Three Locations

Location	CC1	CC2	CC3	CC4	CC5	CC6	CC7
A	1000	3500	500	3000	1250	750	10,000
B	2500	500	3000	2000	750	1250	10,000
C	1250	1750	1000	1500	3500	1000	10,000

For the In-Delta Storage finger printing study, the sum of the concentrations of the conservative tracer constituents 1-6 at any specified location equals the initial specified concentration of 10,000 units. (Equation 1). The value of conservative tracer constituent 7 at any location in the system should also equal the specified concentration as shown in Equation 2. Utilizing a tracer concentration of 10,000 units for each water source, the relative contribution of a specified source, n, at a given location is given by Equation 3, where CCn is the concentration of the conservative tracer constituent associated with the source n. Note that the relationships specified in Equations 1 - 3 are valid for conservative tracer concentrations of 10,000 units at each source location.

$$\sum_{n=1}^{6} CCn = 10,000 \; units \quad \text{at any given location in the Delta} \qquad \text{Eqn. 1}$$

$$CC7 = 10,000 \; units \quad \text{at any given location in the Delta} \qquad \text{Eqn. 2}$$

$$\mathrm{Re}lative \; contribution \; of \; source \, n \, (\%) = \frac{CCn}{10,000 \; units} * 100\% \qquad \text{Eqn. 3}$$

For this study, twenty eight simulation output locations were chosen to provide a full coverage throughout the Delta including the intake and release locations for the Delta Wetlands project. The 28 output locations are shown in Figure 4.

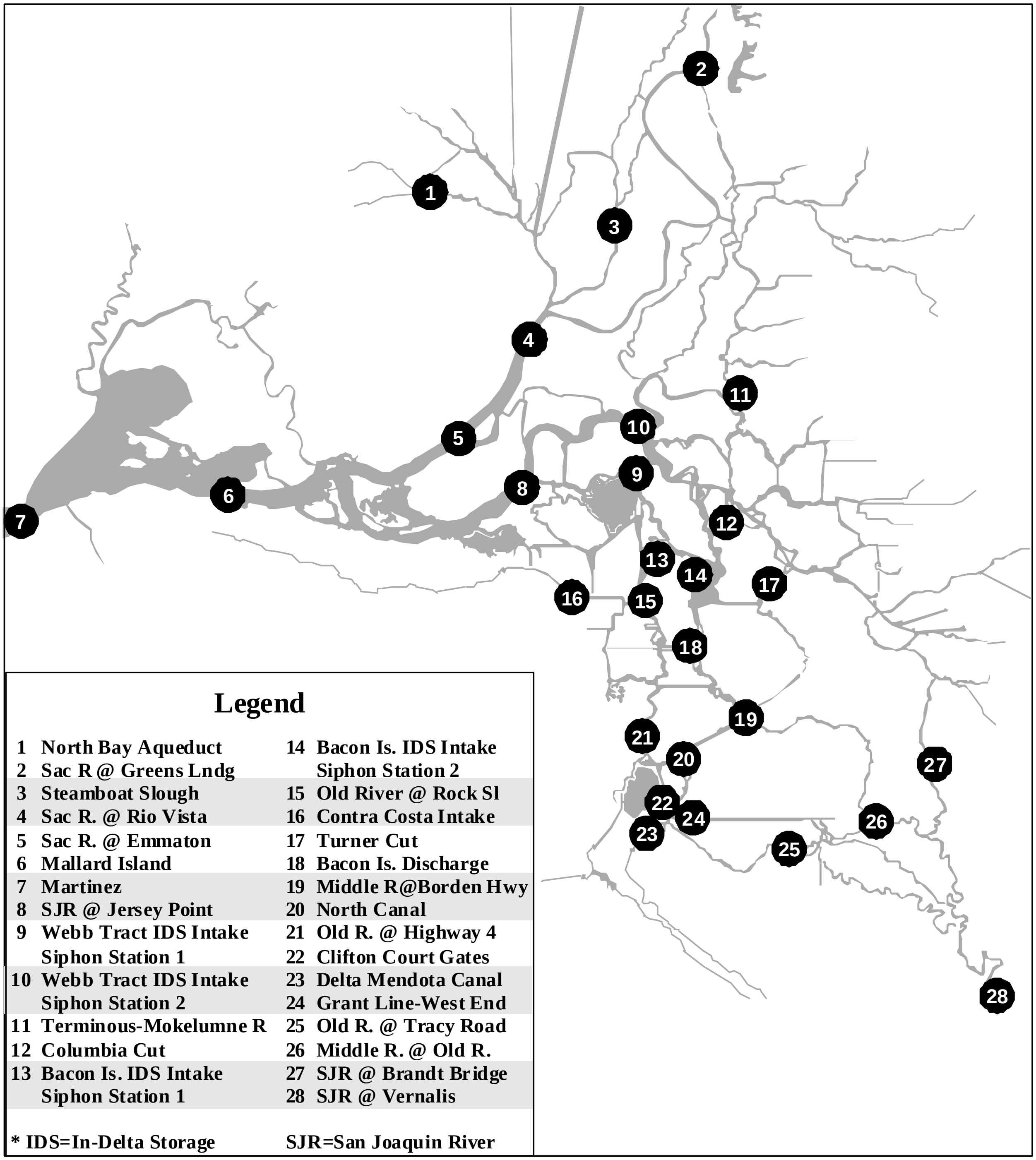


Figure 4: Validation Finger Printing Study Output Locations

Hydrology

The validation fingerprinting study simulates conditions for the time period March 1991 through September 1998. The distribution of water year types for this time period are presented in Figure 5 and Table 4.

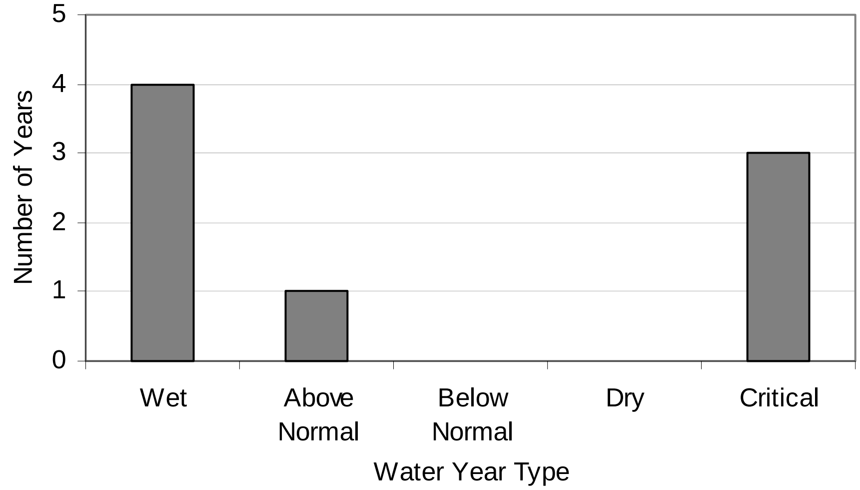


Figure 5: Distribution of Water Year Types for March 1991-September 1998

Table 4: Water Year Designations for 1991-1998

Water Year	SAC 40-30-30
1991	Critical
1992	Critical
1993	Above Normal
1994	Critical
1995	Wet
1996	Wet
1997	Wet
1998	Wet

Simulation Results

Time Series of Simulated Results

Simulation results were analyzed at several locations throughout the Delta (Figure 4). Four of the analysis locations correspond to export locations: Old River Rock Slough, Old River at Highway 4 (Los Vaqueros), Clifton Court Forebay, and the Delta Mendota Canal intake. Four additional analysis locations correspond to the original proposed intakes for the Delta Wetlands project: Webb Tract Intakes 1 and 2, and Bacon Island Intakes 1 and 2. Time series of relative flow contributions of the six water sources are shown for the export locations in Figure 9 and for the original Delta Wetlands intake locations in Figure 10. During dry hydrologic conditions of the first several years of the simulation, inflows from the Sacramento River provide the largest flow contribution at all eight locations. During the wetter hydrologic conditions in the last few years of the simulation, flow contributions from the San Joaquin River increase. Flow contributions from agricultural drainage rarely exceed 20% throughout the simulation period at all eight locations.

Comparison of monthly average flow contributions

Monthly distributions of relative flow contributions from six sources over the study period are shown in Figure 11 for the export locations and in Figure 12 for the original proposed Delta Wetlands intake locations. For Rock Slough, Clifton Court Forebay, and the Delta Mendota Canal intake, Sacramento River flows dominate during the summer, fall, and early winter months with flow contributions ranging from 40%-90%. However, during the winter and spring, flow contributions from the San Joaquin River approach and at times exceed those from the Sacramento River. At Clifton Court Forebay, flow contributions from the San Joaquin River exceed those from the Sacramento River in February through June. For the Old River at Highway 4 site, flow contributions from the San Joaquin River are greater throughout the year than for the other three export locations. Similar to the Clifton Court location, flow contributions from the San Joaquin River exceed those of the Sacramento River in February through June. For both the Clifton Court and Old River at Highway 4 locations, flow contributions from the San Joaquin River can exceed 60% during the winter and spring months. Flow contributions from agricultural drains were highest during the late winter and middle summer months. However, the flow contribution from the agricultural drains never exceeded 15%. All other sources contributed less than 10% of the flow in any given month.

For the Delta Wetlands sites, Sacramento River flows typically dominated. For both Webb Tract Intake locations, flow contributions from the Sacramento River ranged from 55% to 90% for all months. Flow contributions from the San Joaquin River were minor at the Webb Tract intake locations during the summer and fall months. During the winter and spring months, flow contributions from the San Joaquin River increased, but never exceeded 40%. Flow contributions at intake 2 at Bacon Island follow a similar pattern to the Webb Tract intakes. However, intake 1 at Bacon Island shows more influence from the San Joaquin River. Flow contributions from the San Joaquin are typically less than 20% during the summer and fall months, but increase to more than 60% during the winter and spring months. For all four intake locations, flow contributions from agricultural drains were highest during the late winter and middle summer months. However, the total flow contribution from the agricultural drains never exceeded 15%. All other sources contributed less than 10% of the flow in any given month.

Comparison of flow contributions during winter months for wet and dry years

Since high DOC concentrations are typically an issue of concern during wet months, the finger printing results were analyzed on a monthly basis. Since DOC concentrations tend to increase after major rainfall events, the monthly flow contributions for wet and critical years were analyzed separately. Relative flow contributions for the months of December and January in wet and dry years are shown for the eight analysis locations in Figure 13 through Figure 20. Relative flow contributions of the Sacramento River, San Joaquin River, and agricultural drainage during wet and dry years are summarized in Table 5 for the month of December and in Table 6 for the month of January.

At Old River at Rock Slough, the wintertime flow contributions of the San Joaquin River are much greater during the wet years (15% in December and 29% in January) compared to dry ones. For Old River at Rock Slough, San Joaquin River flow contributions are almost negligible during the critical years when the Sacramento River flow contributions were 90% or more during the winter months. Although wintertime flow contributions from agricultural drainage were less than 5% during dry years, these flow contributions exceeded the San Joaquin River's flow contributions of less than 2%. The largest flow contributions from agricultural drainage occurred during January of wet years, when 10% of the flow was provided by agricultural drainage.

A similar pattern of flow contributions results at Old River at Highway 4 (Los Vaqueros). Flow contributions of the San Joaquin River were much greater during wet years (27% in December and 36% in January) than in dry ones. During critical years, at Old River at Highway 4 the San Joaquin River contributed only 7% of the flow in December and only 2% of the flow in January. During the critical years, the Sacramento River flows dominated with contributions of 81% and 88% in December and January respectively. During wet years, the flow contributions from the Sacramento River dropped to 63% and 47% in December and January respectively. Agricultural drainage flow contributions during the winter months were typically around 6% except in January of wet years when the contribution increased to 12%.

At the two south Delta export locations, Clifton Court Forebay and the Delta Mendota Canal, the major flow contribution depended on the year type. During wet years the San Joaquin River provided the majority of the flow at the two export locations, and during dry years the Sacramento River contributed the majority of the flow. During wet years, the San Joaquin River contributed 52% and 57% of the flow at the Clifton Court Intake and 55% and 61% of the flow at the Delta Mendota Canal in December and January respectively. However during critical years, the Sacramento River provided the majority of the flow at Clifton Court Intake and the Delta Mendota Canal. During critical years Sacramento River flow contributions at Clifton Court Intake were 64% for both December and January, and flow contributions at Delta Mendota Canal were 56% for both December and January. Agricultural drainage flow contributions at both locations ranged from 4% to 7% for the winter months except in January of wet years when flow contributions increased to 10% at the Clifton Court Intake and 13% at the Delta Mendota Canal.

During winters of dry years all four original Delta Wetlands intake locations were dominated by Sacramento River flows. For the two Webb Tract intakes and Bacon Island Intake 1, Sacramento River flow contributions exceeded 90% in December and January of critical years. Flow contributions from the Sacramento River during critical years were slightly lower at Bacon Island Intake 2 (the southeastern most intake location) with values of 79% and 88% for December and January respectively. During wet years, the main source of flow at each intake location is the Sacramento River, but flow contributions are lower than in critical years. At the Webb Tract intakes, the Sacramento River contributes around 84% and 62% of the flow in

Table 5: Relative Flow Contributions of the Sacramento River, San Joaquin River and Agricultural Drains during December of Wet and Dry Years

Location	Sac Contribution Dec Wet Years	SJR Contribution Dec Wet Years	Ag Contributions Dec Wet Years	Sac Contribution Dec Critical Years	SJR Contribution Dec Critical Years	Ag Contributions Dec Critical Years
Old River at Rock Slough	76.2	15.0	5.3	89.8	1.6	3.7
Old River at Hwy 4	62.9	27.7	6.1	81.0	6.8	5.9
Clifton Court Intake	42.0	51.5	3.9	63.7	24.9	5.6
Delta Mendota Canal	38.2	55.2	4.2	55.8	33.7	5.3
Webb Tract Intake 1	83.0	8.1	3.5	92.9	0.4	2.7
Webb Tract Intake 2	84.2	6.6	2.9	94.4	0.3	2.3
Bacon Island Intake 1	78.0	13.3	4.9	90.6	1.2	3.4
Bacon Island Intake 2	63.0	25.0	6.1	78.8	8.1	5.5

Light gray shading indicates the major flow source at the specified location for the specified time period

Table 6: Relative Flow Contributions of the Sacramento River, San Joaquin River and Agricultural Drains during January of Wet and Dry Years

Location	Sac Contribution Jan Wet Years	SJR Contribution Jan Wet Years	Ag Contributions Jan Wet Years	Sac Contribution Jan Critical Years	SJR Contribution Jan Critical Years	Ag Contributions Jan Critical Years
Old River at Rock Slough	55.9	29.2	9.6	93.4	0.3	4.1
Old River at Hwy 4	47.1	36.4	11.8	87.9	2.3	6.7
Clifton Court Intake	29.9	56.8	10.1	64.2	26.3	6.8
Delta Mendota Canal	23.2	61.1	13.4	56.2	34.9	6.6
Webb Tract Intake 1	60.5	22.7	8.0	94.8	0.1	3.2
Webb Tract Intake 2	63.5	15.0	7.5	95.4	0.1	3.1
Bacon Island Intake 1	57.3	27.4	9.7	93.7	0.3	3.8
Bacon Island Intake 2	46.8	30.8	13.6	87.5	2.3	5.9

Light gray shading indicates the major flow source at the specified location for the specified time period

December and January. Sacramento River flows are also the major contribution at Bacon Island during wet winters, however contributions are greater for the western intake (Intake 1-flow contributions of 78% in December and 57% in January) than the eastern intake (Intake 2-flow contributions of 63% in December and 47% in January). At all four intake locations, San Joaquin River flow contributions are minor during critical years. However the San Joaquin River's flow contributions increased during wet winters. During wet winters at Webb Tract the San Joaquin River contributes 8% and 7% of the December flows at intakes 1 and 2 respectively. In January the San Joaquin River flow contributions increased to 23% and 15% at intakes 1 and 2 respectively. For Bacon Island during wet winters, San Joaquin flow contributions were higher than at Webb Tract with December flow contributions of 13% and 25% and January flow contributions of 27% and 31% at intakes 1 and 2 respectively. Wintertime agricultural drainage flow contributions were less than 6% at all intake locations except during January of wet years when agricultural drainage flow contributions increased to about 8% at the Webb Tract intakes and 10% at Bacon Island Intake 1 and 14% at Bacon Island Intake 2.

Use of Finger Printing to Estimate DOC Concentrations

DOC concentrations can be estimated utilizing the relative flow contributions determined by the DSM2 finger printing analysis. The DOC contribution at a given location from a specified source can be estimated by multiplying the DOC concentration of that source by the percent contribution of that source at that location. The total DOC concentration at the given location can be estimated by summing the estimated DOC contributions from each source (Eqn. 4).

$$DOC\ at\ a\ location = \sum_{Sources} DOC\ concentration\ source * \mathrm{Re}lative\ contribution\ of\ source \quad \text{Eqn. 4}$$

Note that using equation 4 and the relative flow contributions determined using the DSM2 fingerprinting analysis provides an estimate of DOC concentrations. This methodology does not account for field conditions other than flow rates and source concentrations. The type of finger printing used for this analysis indicates the relative contributions of each source to flow at a specified location, but there is no indication of the temporal distribution of the flow from each source. For example, the Sacramento River contribution at any given location may be composed of water that entered the Delta at different times and of different qualities. The analysis presented here considers all of the water contributed from a specified source to have a constant water quality. Thus affects of antecedent conditions and complex chemical interactions are not accounted for in this methodology.

To illustrate the use of finger printing results to estimate DOC concentrations, DOC concentrations were estimated at Old River at Highway 4 (Los Vaqueros) for wet and critical winters (Figure 6 and Figure 7 respectively). DOC source concentrations were assumed to be 0 mg/l at Martinez, 15 mg/l for the agricultural drainage, 5 mg/l for the San Joaquin River, and 3 mg/l for the eastside streams and Yolo Bypass. DOC source concentrations for the Sacramento River were varied from 3 mg/l to 6 mg/l to examine the sensitivity of the estimated DOC concentrations at Old River at Highway 4 to the range of DOC source concentrations typically observed in the Sacramento River. Relative flow contributions were determined from the DSM2 fingerprinting analysis. DOC concentrations at Old River at Highway 4 were estimated to range from 4.6 mg/l to 6.0 mg/l during wet years for Sacramento River DOC concentrations of 3 mg/l

Old River at Highway 4 (Los Vaqueros) for Wet Years
Sacramento River DOC = 3 mg/l

Source	Source DOC Concentration	Relative Flow Contribution	DOC Contribution
Sac	***3***	46.4	***1.4***
SJR	5	43.3	2.2
Martinez	0	0.2	0.0
Eastside	3	3.5	0.1
Ag Drains	15	6.3	0.9
Yolo	3	0.3	0.0
		TOTAL DOC	**4.6**

DOC Contribution = Source DOC concentration * Relative Flow Contribution(%)/100

Old River at Highway 4 (Los Vaqueros) for Wet Years
Sacramento River DOC = 6 mg/l

Source	Source DOC Concentration	Relative Flow Contribution	DOC Contribution
Sac	***6***	46.4	***2.8***
SJR	5	43.3	2.2
Martinez	0	0.2	0.0
Eastside	3	3.5	0.1
Ag Drains	15	6.3	0.9
Yolo	3	0.3	0.0
		TOTAL DOC	**6.0**

DOC Contribution = Source DOC concentration * Relative Flow Contribution(%)/100

Figure 6: Sample Computations of Estimated DOC Concentrations at Old River at Highway 4 for Wet Years

Old River at Highway 4 (Los Vaqueros) for Critical Years
Sacramento River DOC = 3 mg/l

Source	Source DOC Concentration	Relative Flow Contribution	DOC Contribution
Sac	***3***	77.2	***2.3***
SJR	5	5.2	0.3
Martinez	0	1.0	0.0
Eastside	3	2.4	0.1
Ag Drains	15	10.2	1.5
Yolo	3	0.2	0.0
		TOTAL DOC	**4.2**

DOC Contribution = Source DOC concentration * Relative Flow Contribution(%)/100

Old River at Highway 4 (Los Vaqueros) for Critical Years
Sacramento River DOC = 6 mg/l

Source	Source DOC Concentration	Relative Flow Contribution	DOC Contribution
Sac	***6***	77.2	**4.6**
SJR	5	5.2	0.3
Martinez	0	1.0	0.0
Eastside	3	2.4	0.1
Ag Drains	15	10.2	1.5
Yolo	3	0.2	0.0
		TOTAL DOC	**6.5**

DOC Contribution = Source DOC concentration * Relative Flow Contribution(%)/100

Figure 7: Sample Computations of Estimated DOC Concentrations at Old River at Highway 4 for Critical Years

and 6 mg/l respectively. Similarly for critical years, DOC concentrations were estimated to range from 4.2 mg/l to 6.5 mg/l for Sacramento River DOC concentrations of 3 mg/l and 6 mg/l respectively.

Sensitivity of estimated wintertime Delta DOC concentrations to DOC source concentrations from agricultural drainage and the Sacramento and San Joaquin Rivers were examined for each of the eight output locations. At each location, source DOC concentrations were varied over the range of values observed in the field. Sacramento River DOC concentrations were varied from 3 to 6 mg/l, San Joaquin River DOC concentrations were varied from 3 to 9 mg/l, and agricultural drainage DOC values were varied from 5 to 35 mg/l. Monthly average DOC concentrations for December and January were estimated at each location for each combination of source DOC concentrations for both wet and critical years.

Figure 8 illustrates ranges of DOC concentrations estimated by varying DOC concentrations at one source (either the Sacramento River, San Joaquin River or agricultural drainage) and holding all other source DOC concentrations constant at values typically observed in the field. To synthesize the analysis results, the eight locations were divided into three groups. Webb Tract intakes 1 and 2 and Bacon Island intakes 1 and 2 were grouped as In-Delta Storage intakes. Old River at Rock Slough and Old River at Highway 4 were grouped as Old River intakes. Finally, Clifton Court and Delta Mendota Canal were grouped together. Average minimum and maximum estimated DOC concentrations for each group were computed for the scenarios varying the DOC source concentrations (Table 7).

Typically maximum estimated DOC concentrations in December and January were higher during wet years than during critical years at all locations for the scenarios varying source DOC concentrations from the Sacramento River, San Joaquin River, and agricultural drainage (Figure 8 and Table 7). Minimum estimated DOC concentrations for December and January were similar for both wet and critical years.

For December and January of critical years, highest average maximum DOC concentrations throughout the system were estimated when DOC concentrations in the Sacramento River were high (Figure 8 and Table 7). This is due to the large flow contributions from the Sacramento River during critical years at all of the sites examined (Table 5 and Table 6). During December and January of critical years, varying the DOC concentrations in the San Joaquin River and in agricultural drainage produced minor changes in estimated DOC concentrations except at Clifton Court and the Delta Mendota Canal. This is due to the fact that the Clifton Court and Delta Mendota Canal sites were the only sites examined where the San Joaquin River made significant flow contributions during critical years (Table 5 and Table 6). Flow contributions from agricultural drainage were less than 7% at all locations during critical years. Thus, for the In-Delta Storage and Old River intakes the DOC of the Sacramento River inflows had the largest effect on estimated DOC concentrations for December and January of critical years. However, at Clifton Court and at the Delta Mendota Canal the ranges of influence on estimated DOC in December of critical years were similar for all three inflows examined (Sacramento River, San Joaquin River, and agricultural drainage). In January of critical years, the inflows from the San Joaquin River and

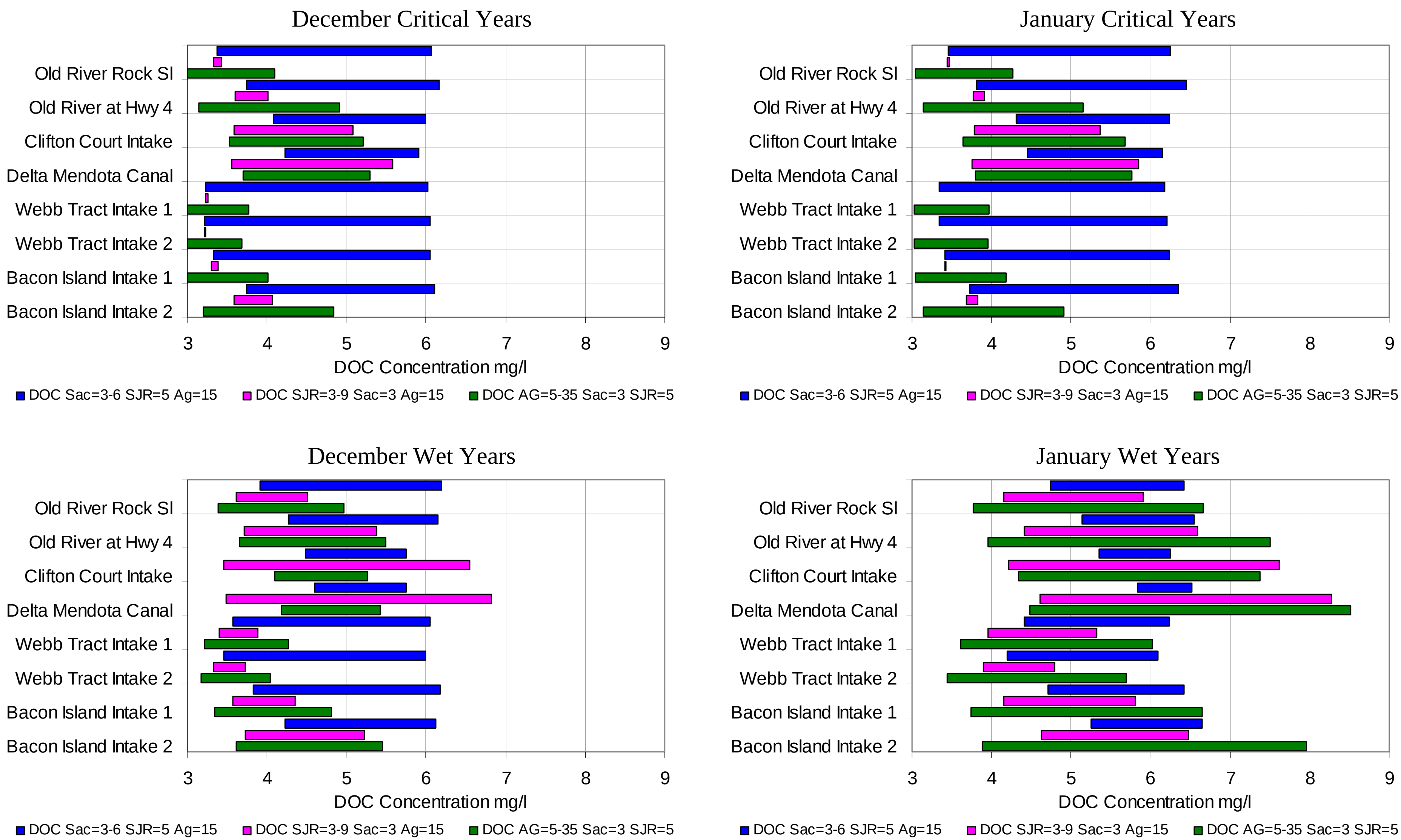


Figure 8: Range of Estimated DOC Concentrations for December and January of Wet and Critical Years

Table 7: Summary of Average Minimum and Maximum Estimated DOC Concentrations

Location	In-Delta Storage Intakes*			Old River Intakes**			Clifton Court and Delta Mendota Canal		
Varied DOC Source	**Sac**	**SJR**	**Ag**	**Sac**	**SJR**	**Ag**	**Sac**	**SJR**	**Ag**
Average Minimum DOC Dec Critical Yrs	3.4	3.3	3.0	3.5	3.5	3.1	4.2	3.6	3.6
Average Maximum DOC Dec Critical Yrs	6.1	3.5	4.0	6.1	3.7	4.1	5.9	5.3	5.2
Average Minimum DOC Dec Wet Yrs	3.8	3.5	3.3	4.1	3.7	3.5	4.5	3.5	4.1
Average Maximum DOC Dec Wet Yrs	6.1	4.3	4.6	6.2	4.9	5.2	5.7	6.7	5.3
Average Minimum DOC Jan Critical Yrs	3.5	3.4	3.1	3.6	3.6	3.1	4.4	3.8	3.7
Average Maximum DOC Jan Critical Yrs	6.2	3.5	4.3	6.4	3.7	4.7	6.2	5.6	5.7
Average Minimum DOC Jan Wet Yrs	4.6	4.2	3.7	4.9	4.3	3.9	5.6	4.4	4.4
Average Maximum DOC Jan Wet Yrs	6.4	5.6	6.6	6.5	6.3	7.1	6.4	7.9	7.9

* In-Delta Storage intakes are Webb Tract intakes 1 and 2 and Bacon Island intakes 1 and 2
**Old River intakes are Old River at Rock Slough and Old River at Highway 4

agricultural drainage had the greatest impact on estimated DOC concentrations at Clifton Court and at the Delta Mendota Canal.

During December and January of wet years, the influence of flow contributions from the San Joaquin River and agricultural drainage becomes more significant in DOC estimations (Figure 8 and Table 7). Similar to the results for critical years, for December of wet years the highest estimated DOC concentrations at the In-Delta Storage and Old River intakes were associated with the high DOC concentrations in the Sacramento River since the Sacramento River was the major flow contributor at those locations during that time period (Table 5). However at Clifton Court and at the Delta Mendota Canal, the San Joaquin River provided the majority of the flow in December and January of wet years (Table 5), and thus the highest estimated DOC concentrations at those locations in those months were associated with high DOC levels in the San Joaquin River. In January of wet years, flow contributions from agricultural drainage increased at all locations (Table 6) and ranged from 7.5% to 13.6%. Although agricultural drainage did not provide the largest flow contribution in January of wet years, the flow contributions became large enough that the largest estimated DOC values throughout the system occurred at the highest agricultural drainage DOC concentrations of 35 mg/l. Thus, a very high source DOC concentration can have a large impact on the total estimated DOC at a given location even if the flow contribution from that source is relatively minor.

Summary-Conclusions

Relative flow contributions from six sources were examined for the time period March 1991 through September 1998. The six sources examined were the Sacramento River, San Joaquin River, Martinez, eastside streams, agricultural drains, and the Yolo Bypass. Simulation results are detailed in this memo for eight selected locations. Four of the analysis locations correspond to export locations: Old River Rock Slough, Old River at Highway 4 (Los Vaqueros), Clifton Court Forebay, and the Delta Mendota Canal intake. Four additional analysis locations correspond to the original intakes for the Delta Wetlands project: Webb Tract Intakes 1 and 2, and Bacon Island Intakes 1 and 2.

Since high DOC concentrations are typically an issue of concern during wet months, the finger printing results were analyzed on a monthly basis. Since DOC concentrations tend to increase after major rainfall events, monthly flow contributions for wet and critical years were analyzed separately. For all eight locations, the Sacramento River provided the major flow contribution during winters of critical years (56%-95%), and San Joaquin River flow contributions were highest during January of wet years (15%-62%). During winters of wet years San Joaquin River flow contributions increased at all locations, and in fact provided the majority of the flow at both the Clifton Court Intake and the Delta Mendota Canal. As might be expected based on their relative locations, San Joaquin River flow contributions were higher for the Bacon Island intake locations than for the Webb Tract locations in both wet and critical years. Agricultural drainage flow contributions were less than 6% at all locations except during January of wet years when the flow contribution increased up to 14%. Agricultural drainage flow concentrations were typically higher at the southern locations (the four export locations and at Bacon Island Intake 2) than at the more northern locations (the Webb Tract intakes and Bacon Island Intake 1).

Finger printing results for flow contributions for the winter months during wet and critical years were utilized to estimate ranges of DOC concentrations at the four export locations and at the four original Delta Wetlands intake locations. During December and January of critical years the highest average maximum DOC concentrations throughout the system were estimated when DOC concentrations in the Sacramento River were high since the Sacramento River provided the major flow contribution during those time periods. During December and January of critical years, varying the DOC concentrations in the San Joaquin River and in agricultural drainage produced minor changes in estimated DOC concentrations except at Clifton Court and the Delta Mendota Canal. This is due to the fact that the Clifton Court and Delta Mendota Canal sites were the only sites examined where the San Joaquin River made significant flow contributions during critical years. Additionally, flow contributions from agricultural drainage were less than 7% at all sites during critical years. In winters of wet years, the highest estimated DOC concentrations were associated with high DOC concentrations for the major flow contributor at each location (the Sacramento River for the In-Delta Storage and Old River intakes and the San Joaquin River for Clifton Court and the Delta Mendota Canal). In January of wet years, flow contributions from agricultural drainage increased to levels that produced the highest estimated DOC concentrations at all locations when the DOC concentrations of the agricultural drainage were high. Thus, a very high source DOC concentration can have a large impact on the total estimated DOC at a given location even if the flow contribution from that source is relatively minor.

In summary, DSM2 finger printing simulations were conducted to analyze the relative flow contributions of six sources throughout the Delta. Simulation results were examined at four export and the four original Delta Wetlands intake locations. Relative flow contributions from the six sources were analyzed as time series over the entire simulation period and on a monthly basis for both wet and critical years. The simulated relative flow contributions were then utilized to conduct a sensitivity analysis of estimated DOC concentrations at the eight study sites. Typically estimated DOC concentrations were highest when there were high DOC levels in the flow source that provided the major flow contribution for winters of both critical and wet years. However, during January of wet years, flow contributions from agricultural drainage increased to levels high enough that the highest estimated DOC concentrations were produced when the DOC concentrations of the agricultural drainage were high. The DSM2 finger printing technique provides a useful tool for sensitivity analysis of boundary condition effects on water quality at selected Delta locations.

References

Nader-Tehrani, Parviz (2001). "Chapter 2: DSM2 Calibration and Validation." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 22nd Annual Progress Report to the State Water Resources Control Board*. California Department of Water Resources. Sacramento, CA.

Pandey, Ganesh (2001). "Chapter 3: Simulation of Historical DOC and UVA Conditions in the Delta." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 22nd Annual Progress Report to the State Water Resources Control Board*. California Department of Water Resources. Sacramento, CA.

Time Series of Simulation Results

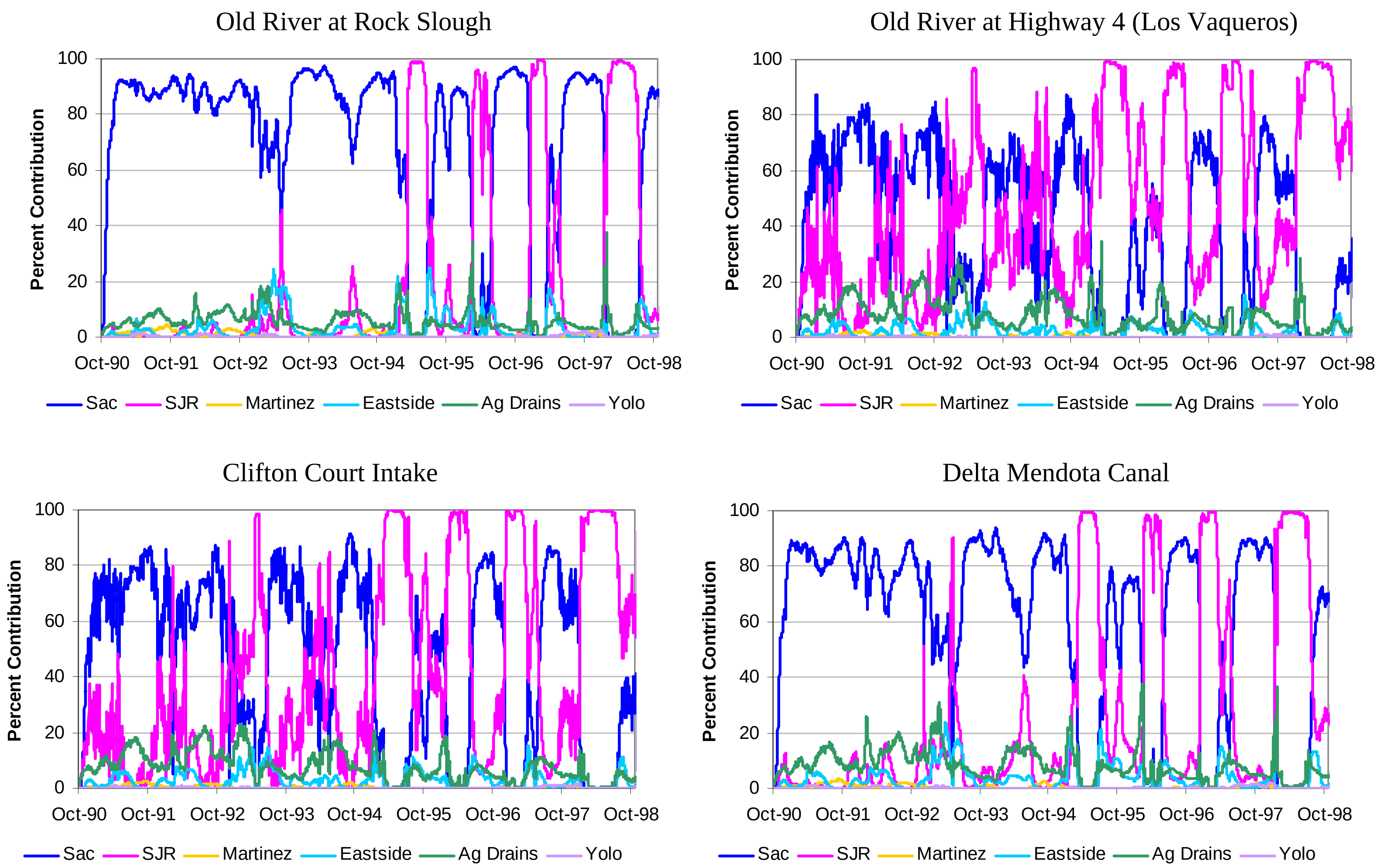


Figure 9: Time Series of Simulated Relative Contributions of Flow Sources at Delta Export Locations

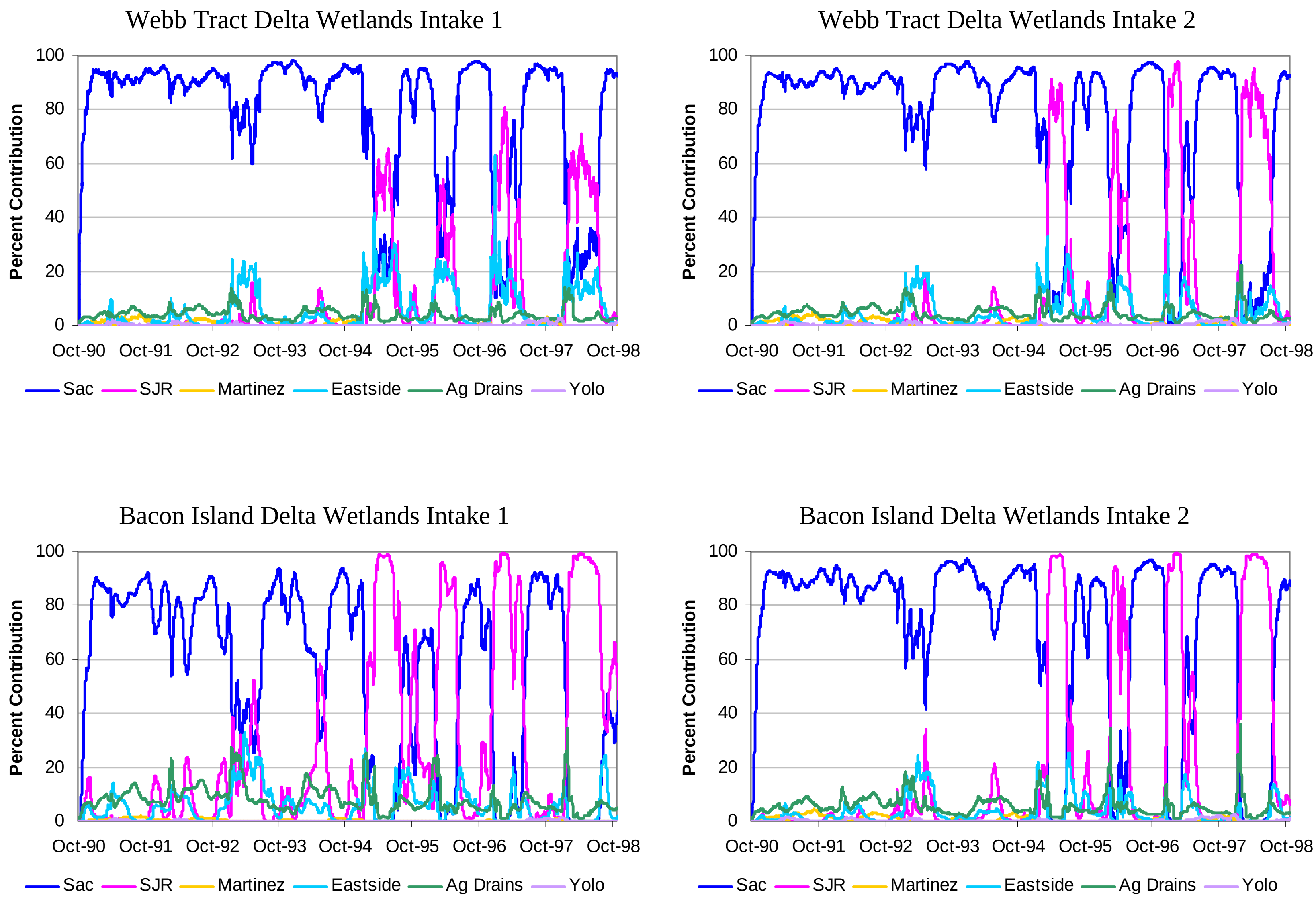
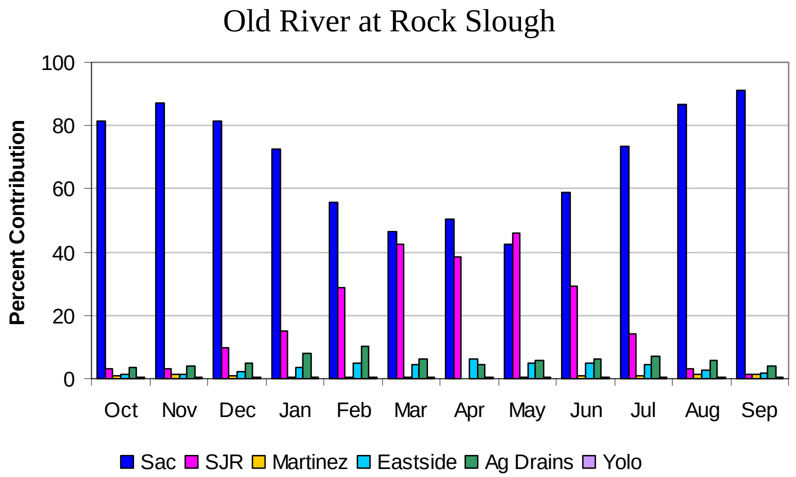
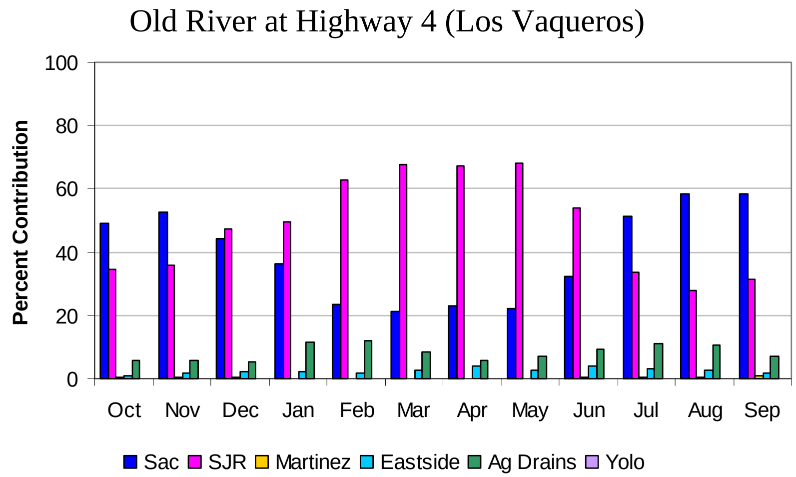
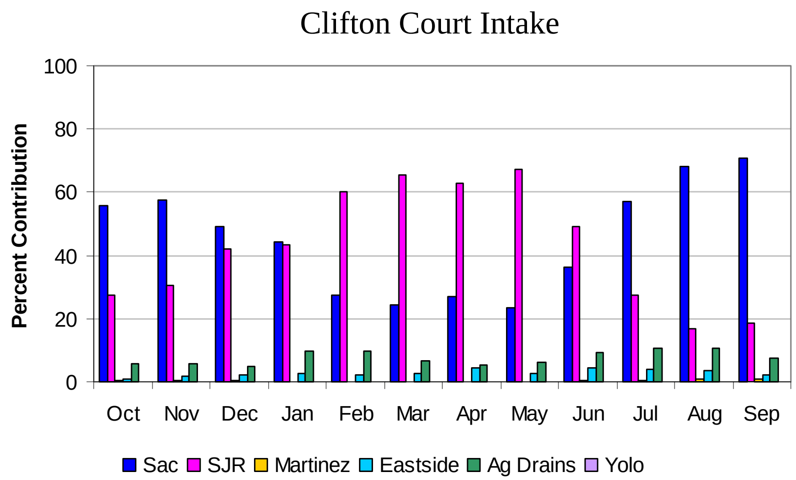


Figure 10: Time Series of Simulated Relative Contributions of Flow Sources at the Original Delta Wetlands Intake Locations

Monthly Average Simulation Results







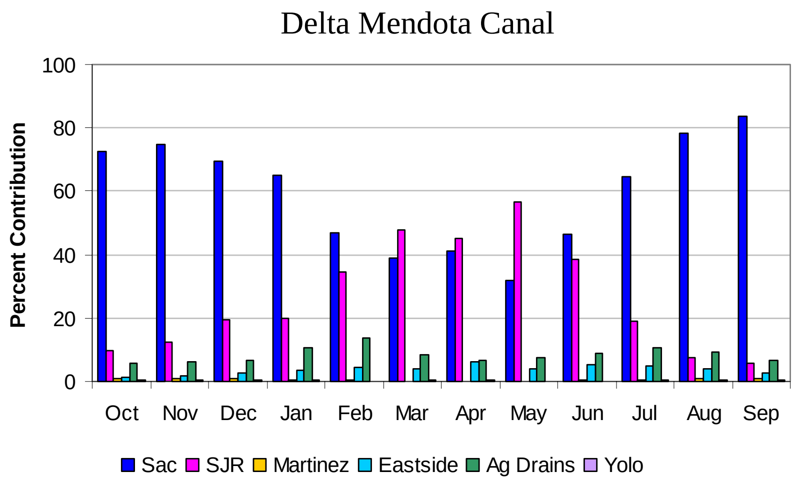


Figure 11: Monthly Average Simulated Relative Contributions of Flow Sources at Delta Export Locations for March 1991-September 1998

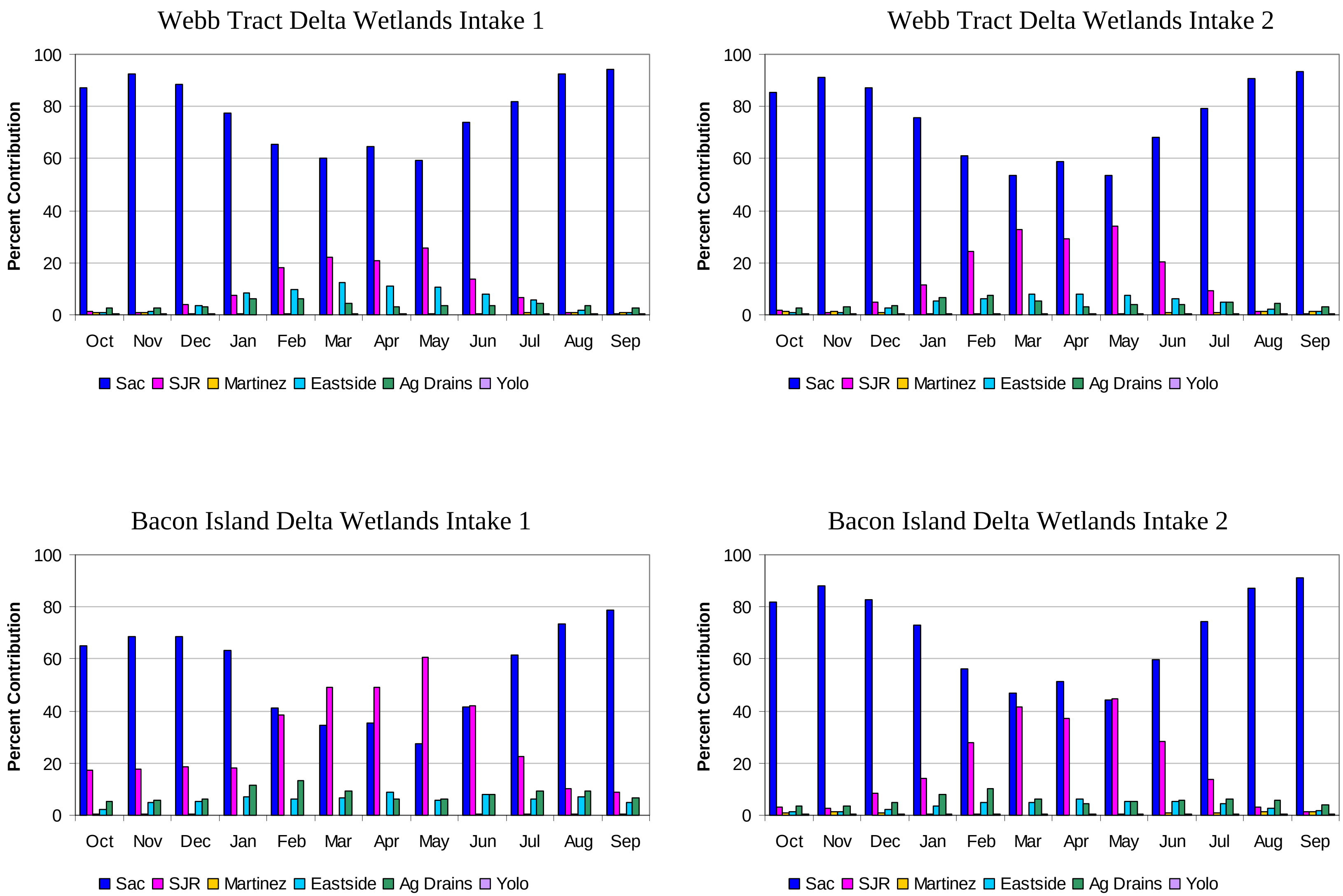


Figure 12: Monthly Average Simulated Relative Contributions of Flow Sources at the Original Proposed Delta Wetlands Intake Locations for March 1991-September 1998

Simulation Results for Winters of Wet and Critical Years

Wet Years **Critical Years**

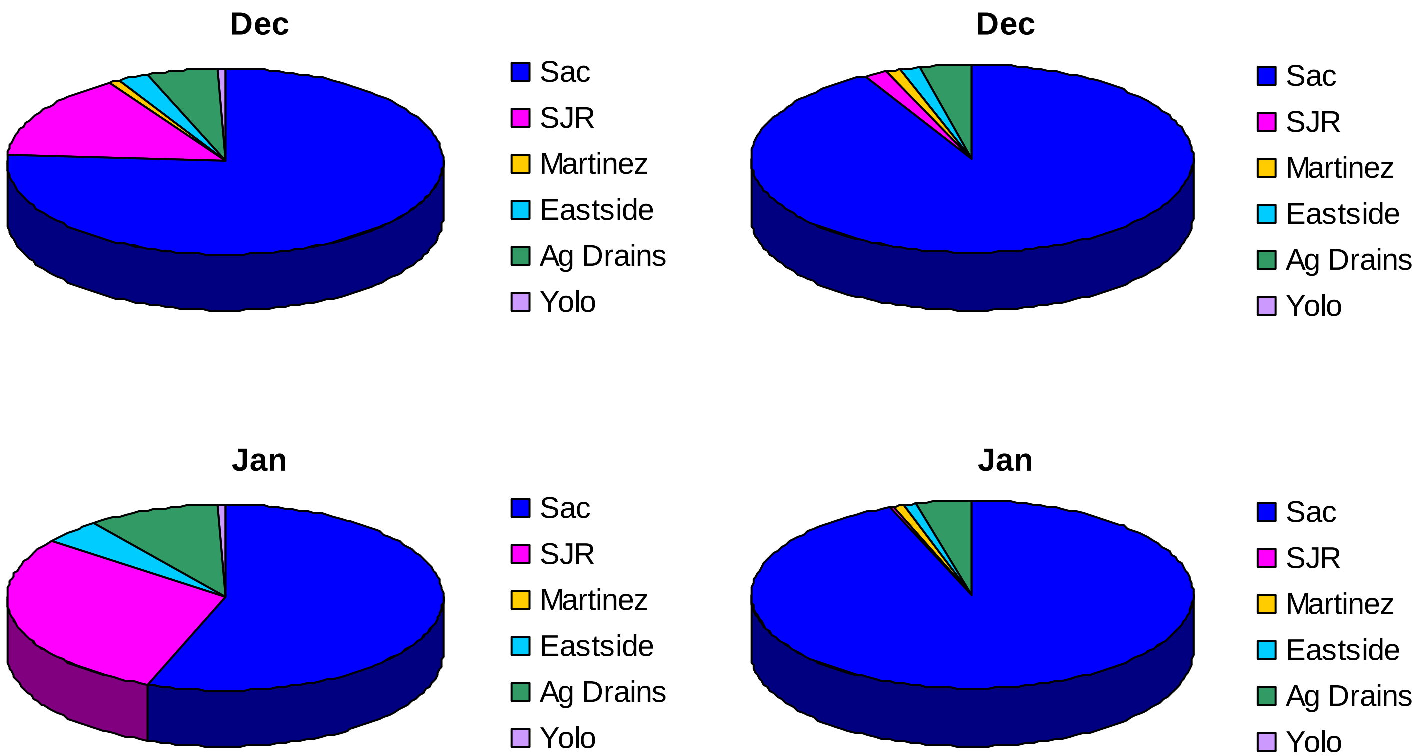


Figure 13: Simulated Relative Contributions of Flow Sources for Old River at Rock Slough for March 1991-September 1998

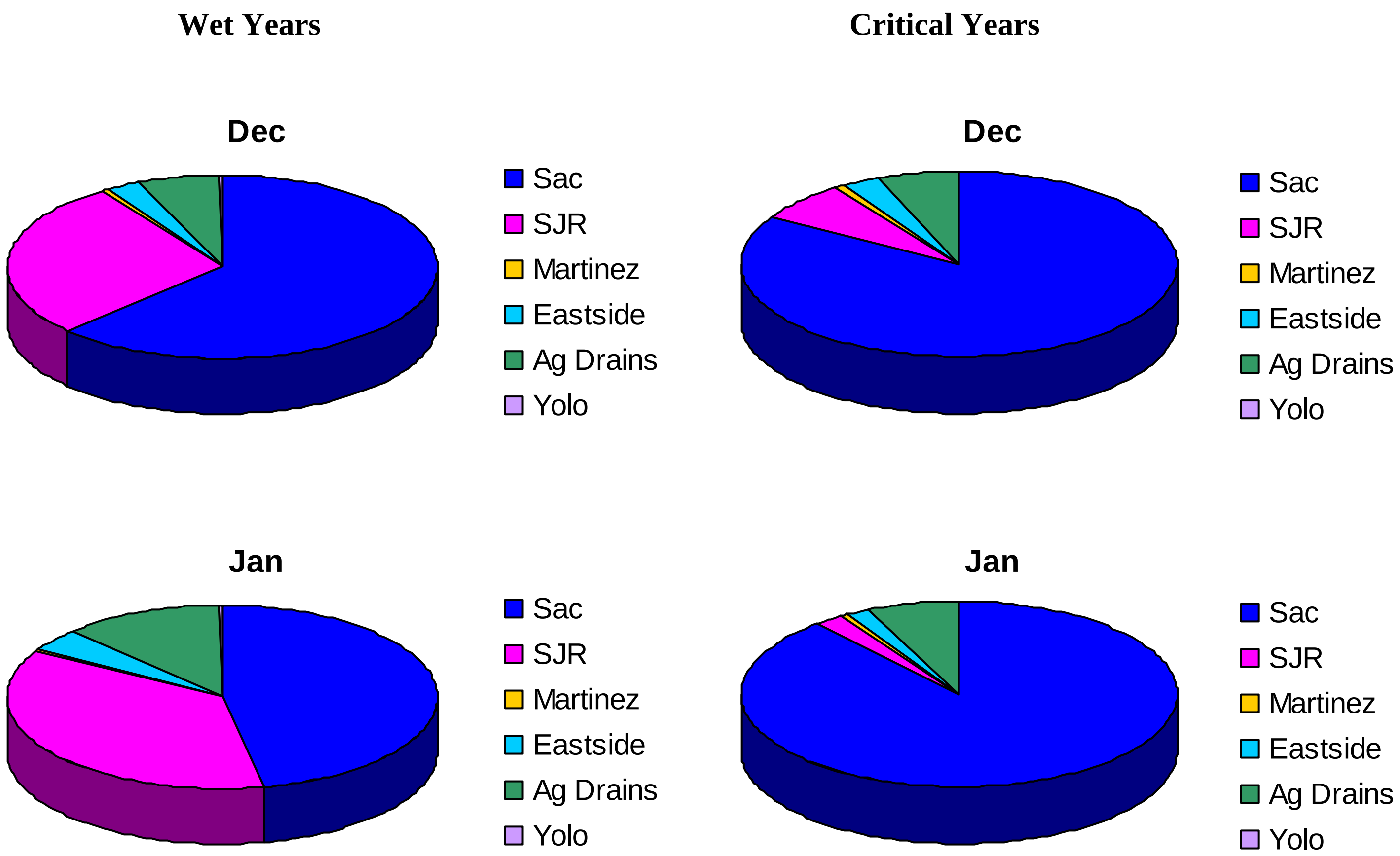


Figure 14: Simulated Relative Contributions of Flow Sources for Old River at Highway 4 (Los Vaqueros) for March 1991-September 1998

Wet Years **Critical Years**

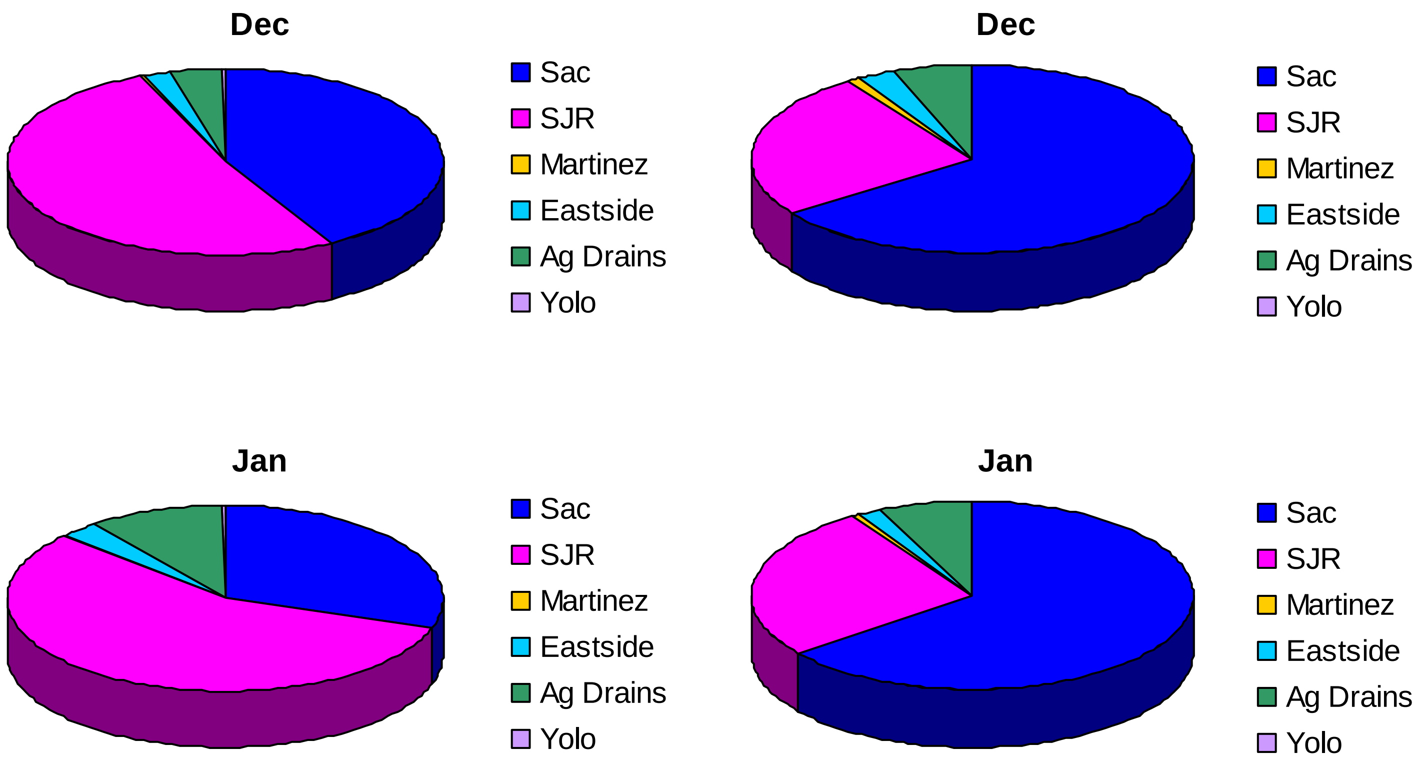


Figure 15: Simulated Relative Contributions of Flow Sources for Clifton Court Intake for March 1991-September 1998

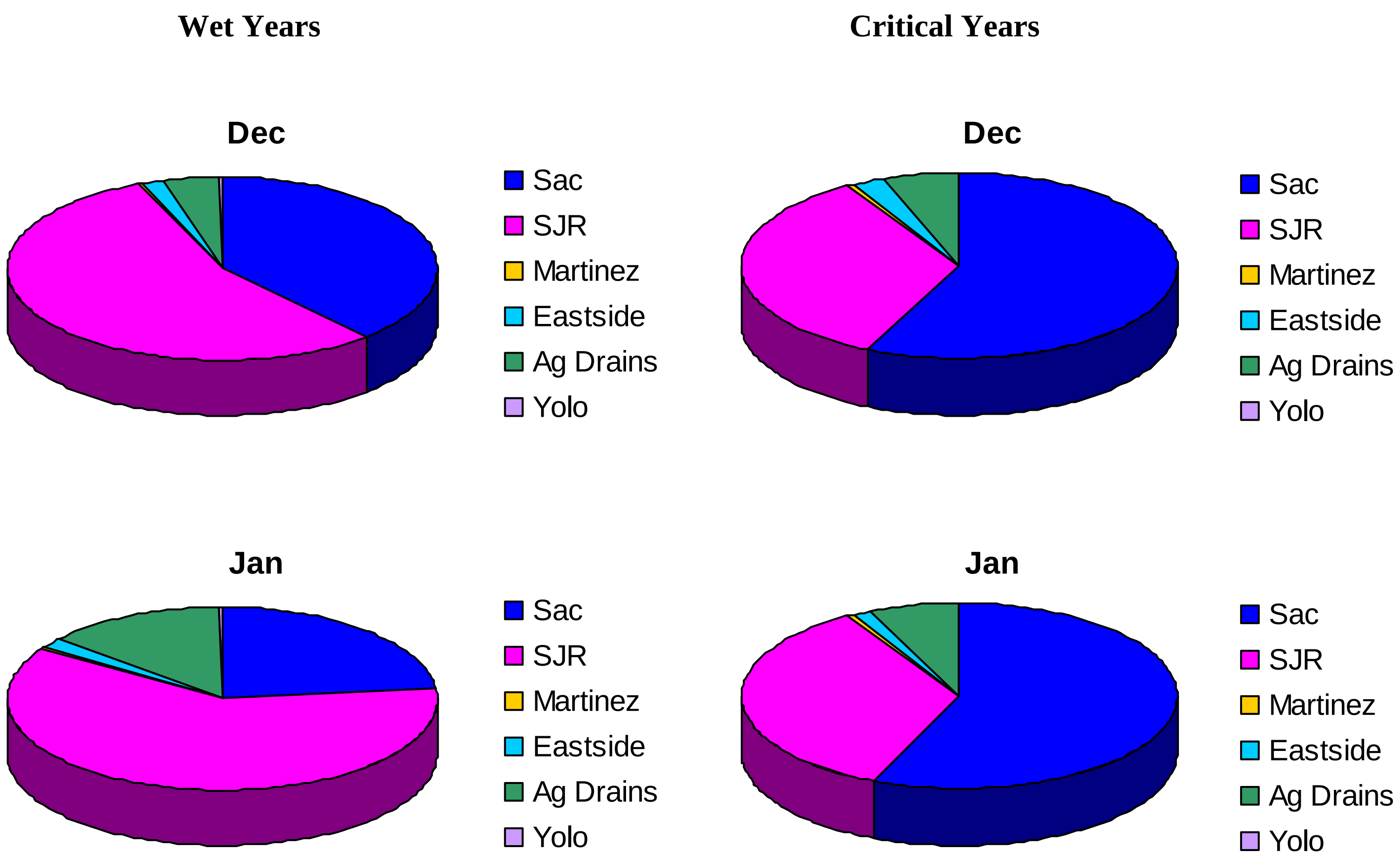
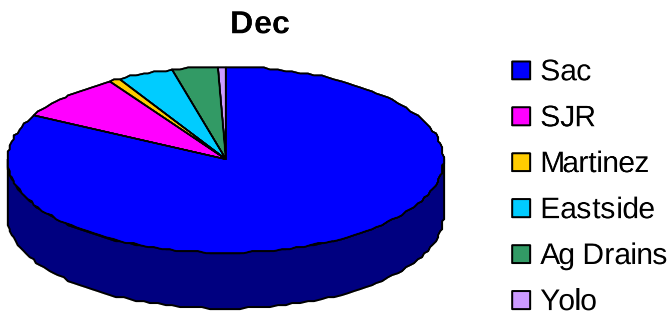
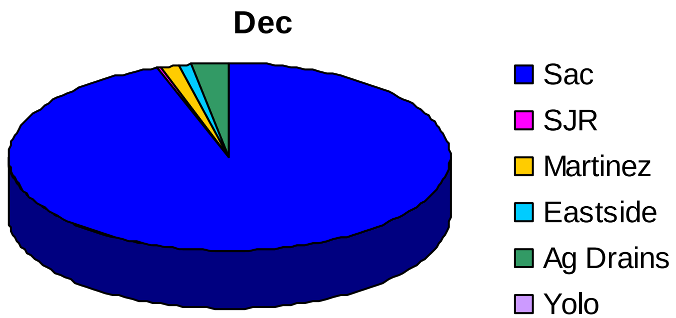
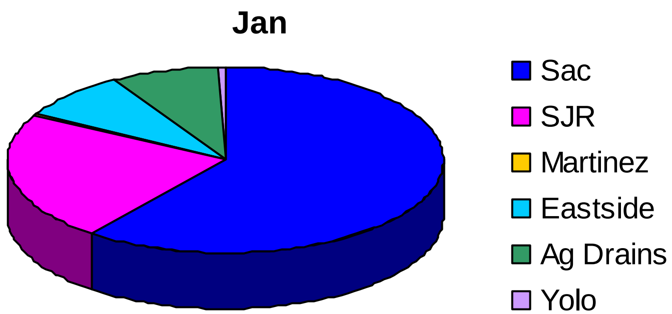


Figure 16: Simulated Relative Contributions of Flow Sources for Delta Mendota Canal for March 1991-September 1998

Wet Years **Critical Years**







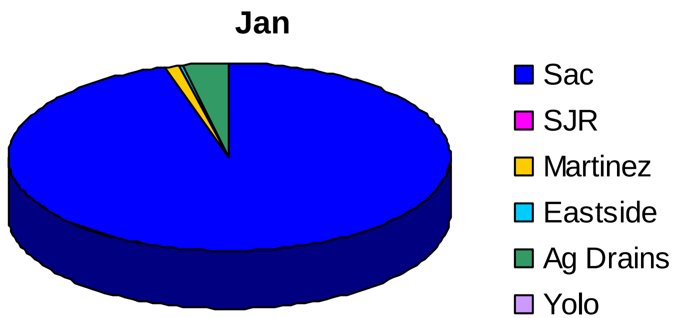


Figure 17: Simulated Relative Contributions of Flow Sources for Webb Tract Intake 1 for March 1991-September 1998

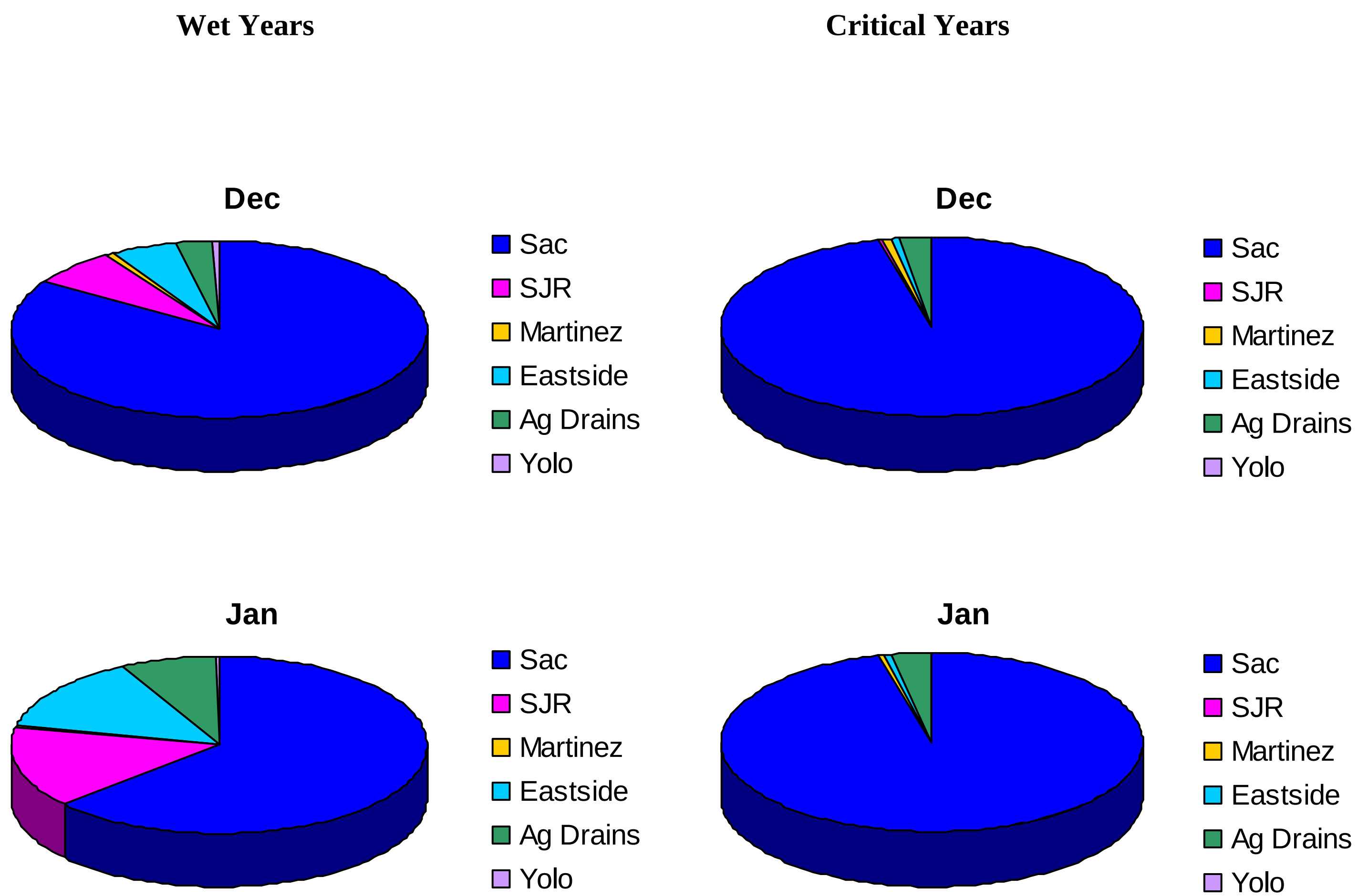


Figure 18: Simulated Relative Contributions of Flow Sources for Webb Tract Intake 2 for March 1991-September 1998

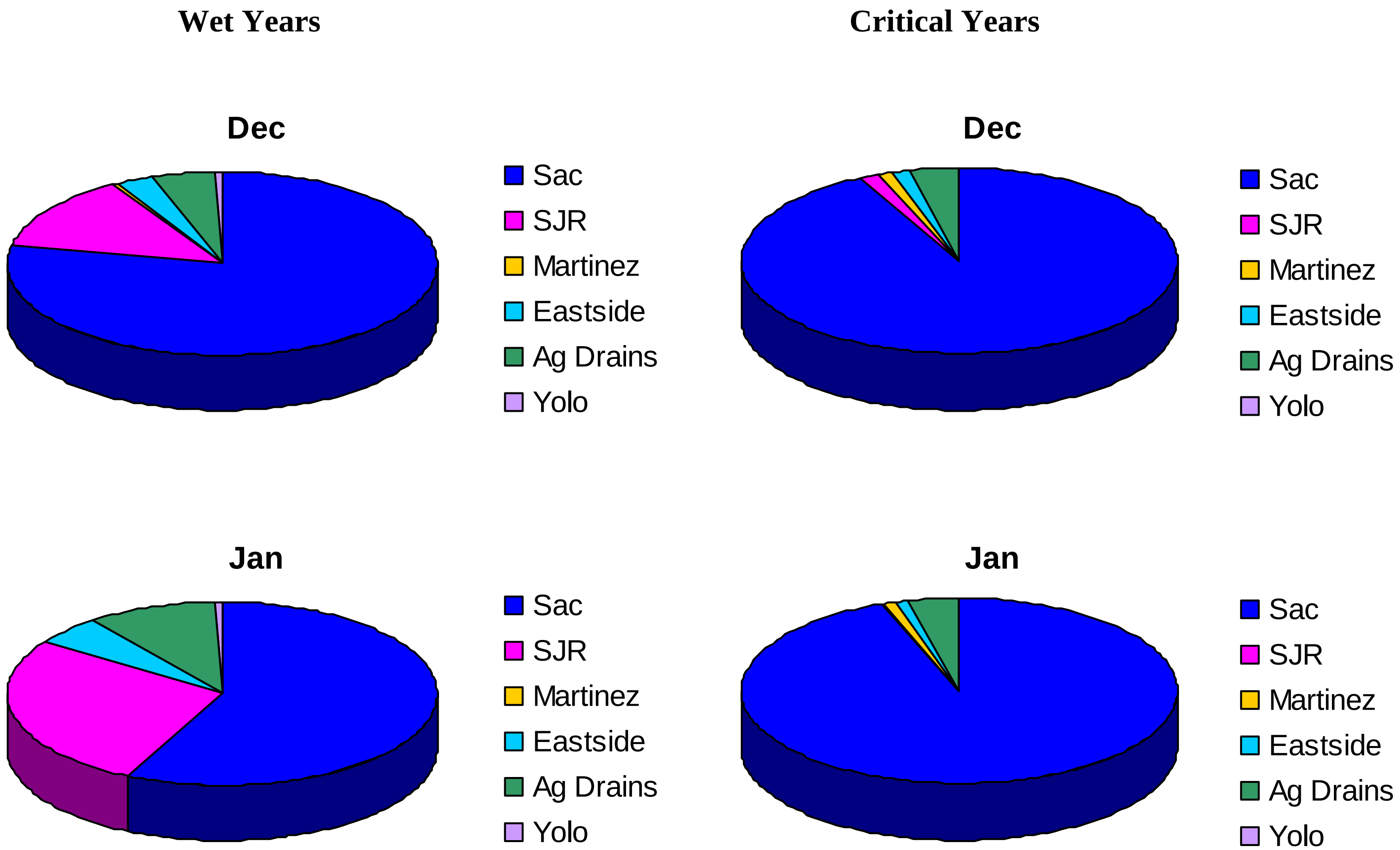


Figure 19: Simulated Relative Contributions of Flow Sources for Bacon Island Intake 1 for March 1991-September 1998

Wet Years **Critical Years**

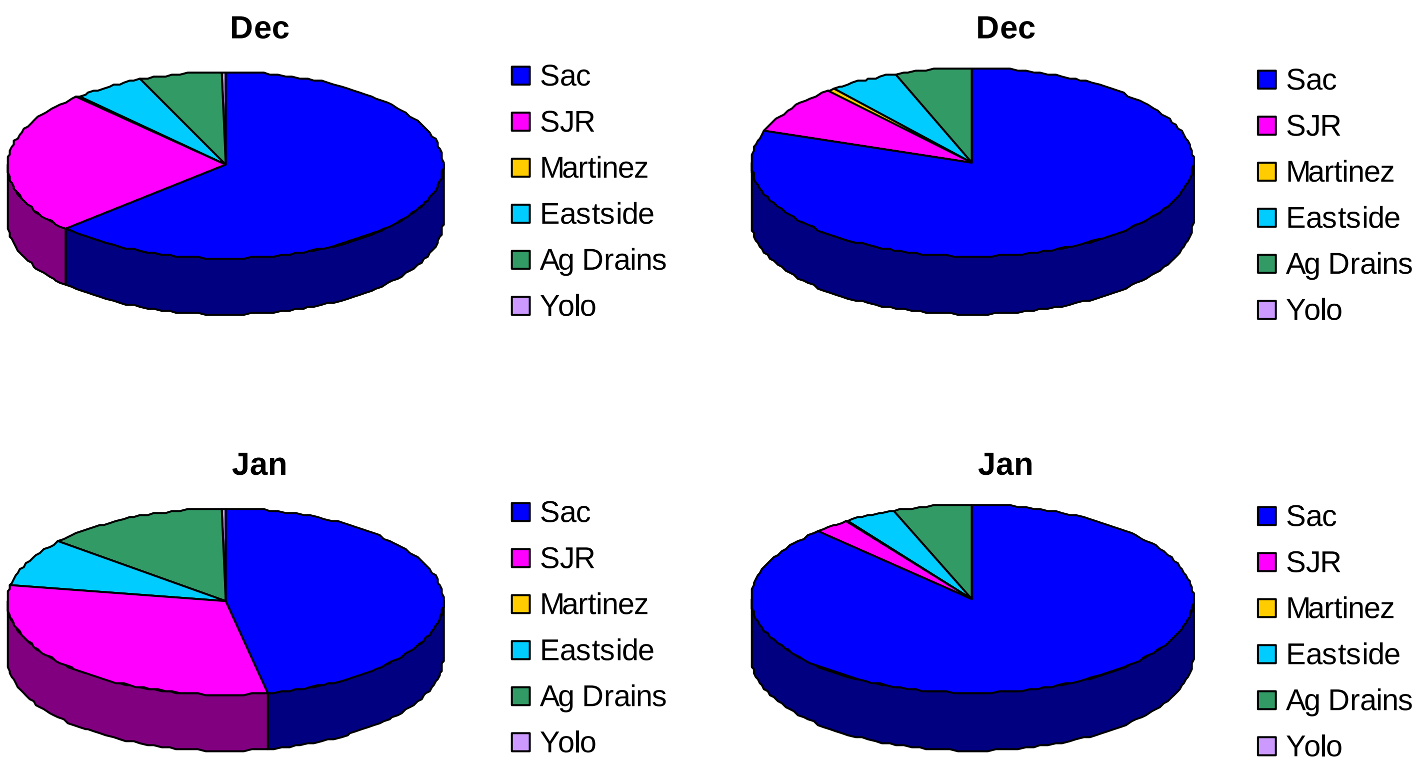


Figure 20: Simulated Relative Contributions of Flow Sources for Bacon Island Intake 2 for March 1991-September 1998